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(71) Applicant *(for all designated States except DE ES FR JP MC PT US)*: FORD MOTOR COMPANY LIMITED [GB/GB]; Eagle Way, Brentwood, Essex CM13 3BW (GB).

(71) Applicant *(for DE only)*: FORD WERKE A.G. [DE/DE]; Werk Koln-Niehl, Henry Ford Strasse, Postfach 60 40 02, D-5000 Köln 60 (DE).

(71) Applicant *(for FR MC only)*: FORD FRANCE S.A. [FR/FR]; B.O. 307, F-92506 Rueil-Malmaison-Cédex (FR).

(71) Applicant *(for ES JP PT only)*: FORD MOTOR COMPANY [US/US]; The American Road, Dearborn, MI 48126 (US).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: MA, Thomas, Tsoi, Hei [GB/GB]; 1 Collingwood Road, South Woodham Ferrers, Essex CM5 5YB (GB).

(74) Agent: MESSULAM, Alec, Moses; A. Messulam & Co., 24 Broadway, Leigh on Sea, Essex SS9 1BN (GB).

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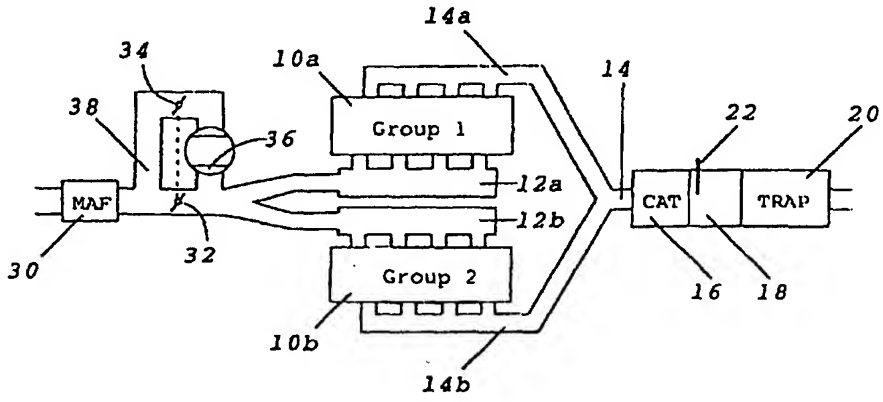

(57) Abstract

A multi-cylinder spark ignition internal combustion engine is described having two groups of cylinders (10a, 10b). One group of cylinders may be selectively disabled by cutting off its fuel supply while continuing to receive air. The exhaust system includes an NO_x trap (20) to store NO_x gases while the exhaust gases contain excess air. During part load operation, the engine is run with one group of cylinders disabled most of the time during which NO_x gases are stored in the NO_x trap (20). In order to permit the trap (20) to be regenerated or purged periodically, both group are fired at the same time for short intervals to supply a stoichiometric or reducing mixture to the exhaust system.

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ENGINE WITH CYLINDER DEACTIVATION

Field of the invention

The present invention relates to a multi-cylinder spark ignition internal combustion engine having two groups of cylinders supplied with intake air through a common main throttle, and disabling means for selectively deactivating one group of cylinders by cutting off its fuel supply.

Background of the invention

Systems for cylinder deactivation have been proposed previously, in order to achieve improved fuel economy and reduced emission when the engine is operating at part load. Such systems rely on the fact that spark ignition engines operate less efficiently at low load because of the pumping losses caused by throttling. Especially in a large engine, it is more efficient to run one group of cylinder under higher load than two groups under lesser load, while producing the same output power. Cutting off the fuel supply to one group of cylinders achieves the desired reduction in fuel consumption but when the disabled cylinders are still allowed to pump air, this upsets the stoichiometry of the exhaust gases and interferes with the operation of the catalytic converter. The presence of excess air in the exhaust gases means that the catalytic converter cannot neutralise NO_x present in the exhaust gases, as this requires a stoichiometric or reducing atmosphere. For this reason, known systems take special steps during cylinder deactivation to avoid air reaching the catalytic converter through the disabled cylinders. The steps that have been proposed for this purpose include maintaining the intake and exhaust valves of the disabled cylinders permanently shut, or running the disabled cylinders with 100% EGR. Both these proposals have disadvantages in that valve disablement is costly to implement and switching to 100% EGR gives rise to

problems in controlling the combustion during the periods of changeover between normal operation and deactivation. Also, undesirable leakage of EGR gases into the intake system of firing cylinders is difficult to avoid.

Summary of the invention

With a view to mitigating the foregoing disadvantages, the invention provides in accordance with a first aspect a multi-cylinder spark ignition internal combustion engine having two groups of cylinders, and disabling means for selectively deactivating one group of cylinders by cutting off its fuel supply, characterised in that the two groups of cylinders are connected to a common exhaust system containing a catalytic converter and a NO_x trap, the disabling means are operative to interrupt the fuel supply to one group of cylinders during part load operation so as to deactivate said one group of cylinders while supplying air to said one group of cylinders, and means are provided for resupplying fuel to said one group of cylinders at periodic intervals to reactivate said one group of cylinders, the duration of the intervals of reactivation being sufficient to regenerate the NO_x trap.

During deactivation of one group of cylinders, air pumped through those cylinders reaches the exhaust system to make the catalytic converter operate only as an oxidation catalyst. Such NO_x as is produced during this time by the firing cylinders is stored in the NO_x trap. At periodic intervals, when both groups of cylinders are activated simultaneously, the exhaust mixture is returned to a stoichiometric or reducing mixture to neutralise the NO_x stored in the NO_x trap, thereby regenerating or purging the NO_x trap.

Another problem with disabling one group of cylinders is that if the cylinder disablement is prolonged, the group

will risk a build up of oil and deposits within the cylinders.

According to a second aspect of the invention, there is provided a multi-cylinder spark ignition internal combustion engine having two groups of cylinders, and disabling means for selectively deactivating one group of cylinders by cutting off its fuel supply, characterised in that the two groups of cylinders are connected to a common exhaust system containing a catalytic converter and a NO_x trap, and the disabling means are operative to interrupt the fuel supply alternately to the two groups of cylinders during part load operation to deactivate one group of cylinders at a time while supplying air to the disabled group of cylinders, there being intervals during changeover of the deactivation during which both groups of cylinders are activated simultaneously, the intervals having sufficient duration to regenerate the NO_x trap.

In this aspect of the invention, the groups are alternately deactivated so that the groups are subjected to equal wear and deposits that may be formed on the combustion chambers during cylinder deactivation will be burnt off more regularly and equally in both groups of cylinders.

Preferably, the intake system has compensation means to reduce the air supply to the two groups of cylinders during the interval when they are activated simultaneously in order to avoid a sudden change in the engine output power.

The compensation means may comprise an electronic throttle that is regulated by a control system to maintain constant output power during the intervals when both groups of cylinders are activated simultaneously. Alternatively, the compensation means may comprise an ON/OFF valve arranged in series with an auxiliary throttle in a passage bypassing the main throttle, the auxiliary and main throttles being ganged

such that the flow through the two passages when the ON/OFF valve is open is always in the same predetermined ratio to the mass air flow through the main throttle alone. In this case, the size of the auxiliary throttle and bypass passage may be calibrated such that the output power when the main throttle alone supplies air to the two groups of cylinders is the same as the output power when both the main and auxiliary throttles supply air to only one of the two groups. In this way, the complexity of an electronic throttle can be avoided and replaced by a simple ON/OFF valve in series with the auxiliary throttle.

While one group of cylinders is deactivated, the other group works under higher load and produces NO_x gases in the exhaust system. These gases cannot be reduced in the three-way catalytic converter because the disabled group of cylinders continues to supply air and create an oxidising atmosphere in the exhaust system. The three-way catalytic converter therefore acts only as an oxidation catalyst to neutralise HC and CO in the exhaust gases and the NO_x trap, which itself incorporated a three-way catalyst, is relied upon to store the NO_x gases until such time as they too can be neutralised when the NO_x trap is purged by supplying it with a stoichiometric or reducing atmosphere.

The NO_x trap has only a limited capacity but the invention allows freedom in setting the time between purging to avoid saturation of the trap. The frequency with which the engine is operated with both groups of cylinders activated simultaneously can be set as desired to ensure that the trap remains at a high storage efficiency. During these intervals, the fuelling can be set to achieve, as desired, a stoichiometric or a reducing atmosphere in the exhaust gases passing through the catalytic converter, to regenerate or purge the NO_x trap fully.

Brief description of the drawings

The invention will now be described further, by way of example, with reference to the accompanying drawings, in which :

Figure 1 is a schematic representation of an internal combustion engine,

Figures 2 and 3 are timing diagrams showing two alternative methods of fuelling the internal combustion engine in figure 1,

Figure 4 is a view similar to Figure 1 of an embodiment having a modified intake system,

Figures 4a and 4b show a detail of the embodiment of Figure 4 in alternative positions of the valve supplying air to the intake manifolds of the two groups of cylinders.

Detailed description of the preferred embodiment

In Figure 1 an internal combustion engine has two groups of cylinders 10a and 10b having intake manifolds 12a and 12b and exhaust manifolds 14a and 14b, respectively. The exhaust manifolds 14a and 14b are joined to one another at a section 14 that precedes an after treatment system consisting of a catalytic converter 16, a burner chamber 18 having an igniter 22 and a NO_x trap 20, which itself contains a three-way catalyst.

The intake system for both groups of cylinders comprises a mass air flow meter 30 connected in series with a main throttle 32 that provides air to both intake manifolds 12a and 12b. In addition, the intake system comprises a bypass passage 38 containing a second throttle 34 ganged with the main throttle 32 and an ON/OFF valve 36 for selectively opening and closing the bypass passage 38 depending on whether one or both groups of cylinders of the engine are activated.

Under high load operation, the ON/OFF valve 36 occupies the position illustrated to disable the bypass passage 38. Fuel is metered to both groups of cylinders so that both groups fire normally and produce an exhaust gas mixture that is stoichiometric and can be purified by the three-way catalysts.

During low and part load operation, the fuel supply to one of the groups 10a and 10b is shut off while the other group continues to fire normally. The air supply to the deactivated group of cylinders is not discontinued and these cylinders pass air into the exhaust system. The three-way catalytic converter in the after treatment system can now only operate as an oxidation catalyst in this oxidising atmosphere and the NO_x produced by the firing group of cylinders cannot be neutralised. To overcome this problem, the invention provides the NO_x trap to store the NO_x gases and prevent them from being discharged to ambient atmosphere.

The NO_x trap has only a finite capacity and this mode of operation cannot be maintained indefinitely if NO_x gases are not to be released to the atmosphere. For this reason it is necessary to regenerate or purge the NO_x trap at regular intervals by running the engine in such a manner as to produce a reducing or stoichiometric exhaust mixture. This is achieved by periodically running both groups of cylinders simultaneously by supplying fuel to both groups for a duration long enough to purge the NO_x trap.

The engine of Figure 1 can be operated in one of two modes. In the first mode the same group of cylinders is always deactivated while in the second mode the deactivation alternates between the two groups of cylinders. The first mode is represented by the fuel timing diagram shown in Figure 2 in which fuel supply is permanently ON to the first group of cylinders and pulsed ON at regular intervals to the

second group of cylinders. The second mode on the other hand is represented by Figure 3 in which both groups of cylinders are switched ON and OFF with the same mark-to-space ratio as one another, this mark-to-space ratio being slightly in excess of 1:1 so that at the changeover between groups there are defined brief purge intervals during which both groups of cylinders are activated simultaneously.

Both modes of operation of the engine achieve the desired purging of the NO_x trap but the second mode has the advantage that the groups are subjected to equal wear and deposits are removed more regularly from the disabled cylinders.

At the times that the engine operates with all cylinders firing, it will tend to produce more output power than when one group is deactivated for a given position of the main throttle 32. The purpose of the ON/OFF valve 36 is to avoid changes in engine output power during the purge intervals and during the changeover between one group and two groups operation. When one group is disabled, the ON/OFF valve 36 is turned to its fully open position to allow air to flow through the bypass passage 38 and the second throttle 34. This latter throttle 34 is ganged to operate in unison with the main throttle 32 and, for a given position of the main throttle 32, supplies the correct amount of compensation air flow such that the output power from the engine when one group of cylinders is deactivated is the same as the output power when both groups of cylinders are firing.

Exhaust gas ignition systems (EGI) have previously been proposed to accelerate the light-off of a catalytic converter. The engine is intentionally run with an excessively rich mixture so that the exhaust gases contain hydrocarbons, carbon monoxide and hydrogen and additional air is introduced directly into the exhaust system to produce an ignitable mixture that is burnt immediately upstream of the catalytic converter to bring it quickly to

its light-off temperature during cold starts. The burner chamber 18 is provided in the exhaust after treatment system in Figure 1 for this purpose but in the described embodiment of this invention, it is possible to avoid the need for an expensive source of additional air. If one group of cylinders is run with a very rich mixture and the other group is deactivated but continues to receive air, then the resultant mixture will be ignitable in the burner chamber 18 using the igniter 22. If the firing cylinders receive the fuel that should have been burnt by both groups of cylinders, they will be running excessively rich but the resultant exhaust gas mixture reaching the burner 18 will still be stoichiometric and burn completely. The heat released will quickly bring the NO_x trap which also contains a three-way catalyst to its light-off temperature.

The embodiment of Figure 1 suffers from the disadvantage that the disabled group of cylinders will still be partially throttled and would be performing unnecessary pumping work against the manifold vacuum. This disadvantage is avoided in the embodiment of Figure 4 in that unthrottled ambient air is supplied to the deactivated group of cylinders in order to reduce the pumping loss to a minimum.

In the embodiment of Figure 4 like numerals have been used to designate components previously described by reference to Figure 1 in order to avoid unnecessary repetition. The essential difference resides in the connection between the main throttle 32 and the intake manifolds 12a and 12b which in this case includes a diverter valve 40. For ease of description the bypass passage 38 has been omitted it being assumed in this case that the throttle 32 is an electronic throttle but a bypass passage may be used as previously described if preferred to maintain constant output power regardless of engine operating mode.

The diverter valve 40 has two inlet and two outlet ports. The first inlet port, which has no reference numeral is connected to the throttle 32 and the mass air flow meter 30. The second inlet port 46 is directly connected to ambient air and the two outlet ports 42 and 44 lead respectively to the intake manifolds 12a and 12b. The valve has a rotatable diverter element which is V-shaped in cross-section and can be moved between the three positions shown in Figures 4, 4a and 4b respectively.

In the position shown in Figure 4 the diverter element points at the throttle 32 and obstructs the port 46 completely. Only air passing the mass air flow meter 30 reaches the intake manifold 12a and 12b and the valve 40 splits the air in equal amounts. This is the position occupied by the valve 40 during normal operation with all cylinders firing.

The rotation of the diverter element to the position shown in Figure 4a has the effect of connecting the intake manifold 12a to the air passing the intake throttle 32 and the mass air flow meter 30, while connecting the intake manifold 12b to the ambient without throttling the air. This is the position adopted by the valve 40 when the second group of cylinders 10b is deactivated. The first group of cylinders 10a now operates normally while the second group of cylinders 10b operates with the minimum pumping work and delivers air to the exhaust system.

If the same group of cylinders is disabled every time, then the valve 40 need only be capable of movement between the positions shown in Figures 4 and 4a. If however it is desired to be able to switch the deactivation alternately between groups of cylinders, then the valve 40 can be moved further to the position shown in Figure 4b. From the symmetry with Figure 4a it will be appreciated that the only difference this will make is that the first group of

cylinders 10a would be disabled instead of the second group 10b.

An advantage of the embodiment of Figure 4 is that it is very tolerant to leakage in the diverter valve 40. If any leakage does occur, air will enter the firing cylinders. This will not disturb the combustion process but merely cause the mixture strength to be weakened slightly. If the engine is calibrated to supply a nominally stoichiometric mixture to the firing group of cylinders, based on the air flow measured by the mass air flow meter, any leakage that occurs will make the mixture slightly leaner than stoichiometric, which is advantageous in ensuring low hydrocarbon and carbon monoxide in the feed gases supplied to the after treatment system. NO_x may be increased in the feed gases but the storage of the NO_x in a trap and the subsequent purging of the trap will prevent this pollutant from being discharged to atmosphere. Thus the after treatment system can be effective in controlling the discharge of the three main noxious gases without the critical control of the stoichiometry of the exhaust gases that is required when using a three-way catalyst.

CLAIMS

1. A multi-cylinder spark ignition internal combustion engine having two groups of cylinders, and disabling means for selectively deactivating one group of cylinders by cutting off its fuel supply, characterised in that the two groups of cylinders are connected to a common exhaust system containing a catalytic converter and a NO_x trap, the disabling means are operative to interrupt the fuel supply to one group of cylinders during part load operation so as to deactivate said one group of cylinders while supplying air to said one group of cylinders, and means are provided for resupplying fuel to said one group of cylinders at periodic intervals to reactivate said one group of cylinders, the duration of the intervals of reactivation being sufficient to regenerate the NO_x trap.

2. A multi-cylinder spark ignition internal combustion engine having two groups of cylinders, and disabling means for selectively deactivating one group of cylinders by cutting off its fuel supply, characterised in that the two groups of cylinders are connected to a common exhaust system containing a catalytic converter and a NO_x trap, and the disabling means are operative to interrupt the fuel supply alternately to the two groups of cylinders during part load operation to deactivate one group of cylinders at a time while supplying air to the disabled group of cylinders, there being intervals during changeover of the deactivation during which both groups of cylinders are activated simultaneously, the intervals having sufficient duration to regenerate the NO_x trap.

3. An internal combustion engine as claimed in claim 1 or claim 2, wherein the intake system includes compensation means to reduce the air supply to the two groups of cylinders during the interval when they are activated

simultaneously in order to avoid a sudden change in the engine output power.

4. An internal combustion engine as claimed in claim 3, wherein the compensation means comprise an electronic throttle that is regulated by a control system to maintain constant output power during the intervals when both groups of cylinders are activated simultaneously.

5. An internal combustion engine as claimed in claim 3, wherein the compensation means comprise an ON/OFF valve arranged in series with a throttle in a passage bypassing the main throttle, the main and second throttles being ganged such that the flow through the two passages when the ON/OFF valve is open is always in the same predetermined ratio to the mass air flow through the main throttle alone.

6. An internal combustion engine as claimed in any preceding claim, wherein when a group of cylinders is deactivated, that group is connected by a diverter valve to ambient air so that the air supplied to the cylinders of that group is not throttled.

7. An internal combustion engine as claimed in claim 6, wherein the diverter valve has two inlets connected to ambient air and the main throttle, respectively, two outlet ports each connected to the intake manifold of a respective one of the groups of cylinders and a V-shaped rotatable element, the rotatable element having a first position in which the port connected to ambient air is obstructed while the port connected to the main throttle is connected simultaneously to both outlet ports and a second position in which the main throttle is connected to only one of the outlet ports while the inlet port connected to ambient air is connected to other outlet port.

8. An internal combustion engine as claimed in claim 7, wherein the rotatable element of the diverter valve has a third position in which the connections between the inlet and outlet ports are reversed.

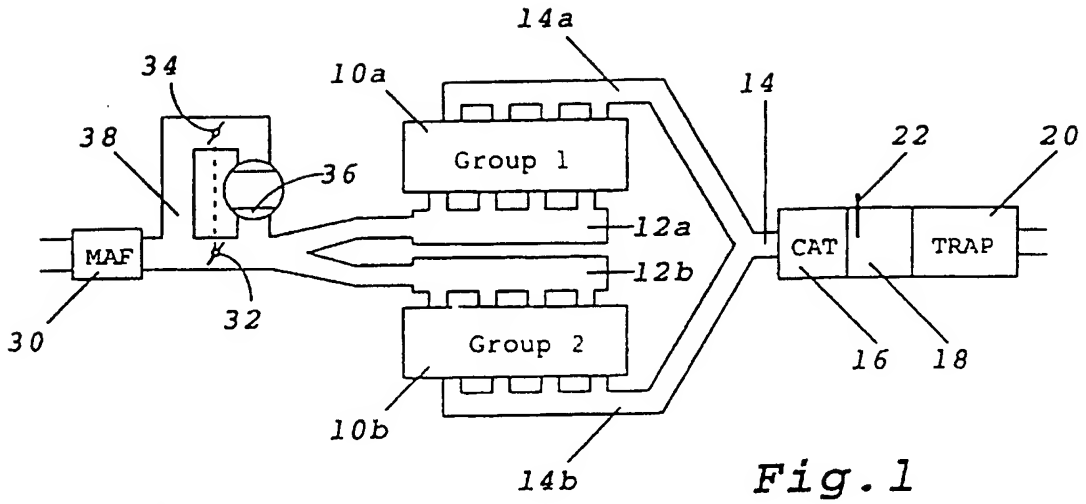

Fig.1

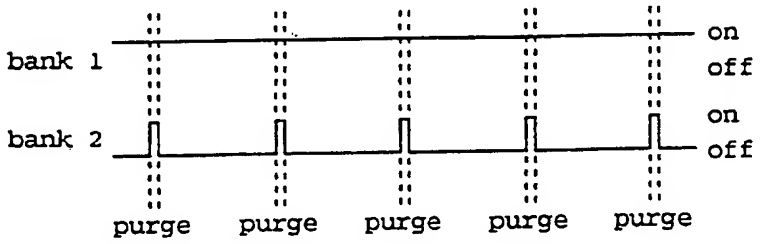

Fig.2

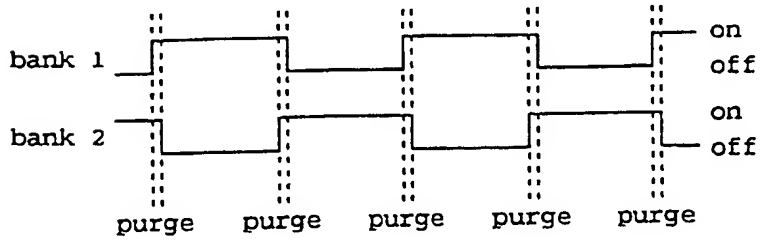

Fig.3

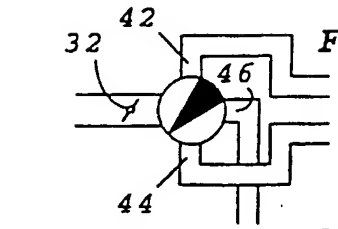

Fig.4a

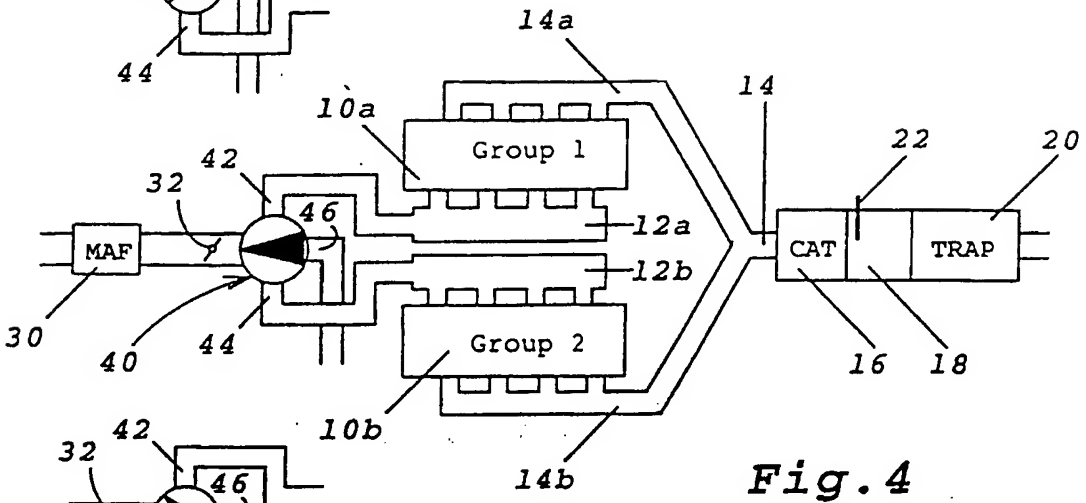

Fig.4

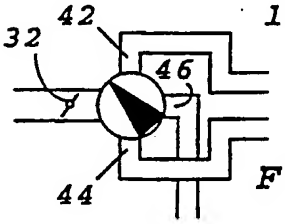

Fig.4b

INTERNATIONAL SEARCH REPORT

Inter. ional Application No
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A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 F02D17/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 F02D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	PATENT ABSTRACTS OF JAPAN vol. 4, no. 64 (M-11) [546] , 14 May 1980 & JP,A,55 029002 (NISSAN), 1 March 1980, see abstract ---	1
A	PATENT ABSTRACTS OF JAPAN vol. 4, no. 92 (M-18) [574] , 3 July 1980 & JP,A,55 049549 (NISSAN), 10 April 1980, see abstract ---	2
A	EP,A,0 627 548 (TOYOTA) 7 December 1994 see abstract; figure 1 ---	1,2
A	EP,A,0 598 917 (TOYOTA) 1 June 1994 see abstract see column 2, line 18 - line 39 --- -/--	1,2

[X] Further documents are listed in the continuation of box C.

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Date of the actual completion of the international search	Date of mailing of the international search report
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C.(Continuation) D CUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	PATENT ABSTRACTS OF JAPAN vol. 7, no. 128 (M-220) [1273] , 3 June 1983 & JP,A,58 047132 (NISSAN), 18 March 1983, see abstract	1
A	PATENT ABSTRACTS OF JAPAN vol. 8, no. 270 (M-344) [1707] , 11 December 1984 & JP,A,59 141740 (NISSAN), 14 August 1984, see abstract	3,4
A	FR,A,2 671 136 (PEUGEOT) 3 July 1992 see abstract; figure 1	1,2
A	US,A,4 146 006 (GARABEDIAN) 27 March 1979 see abstract see column 1, line 5 - line 11 see column 1, line 46 - column 2, line 7	2

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INTERNATIONAL SEARCH REPORT

Information on patent family members

Int. ational Application No
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